



Review on the costs and benefits of renewable energy power subsidy in China



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ABSTRACT

Nowadays, renewable energy plays a vital role in the sustainable development of a society. In China, renewable energy power has developed rapidly since the implementation of *Renewable Energy Act*. Through a series of specific incentive measures, especially subsidy policies, China's renewable energy power has made great achievements both in technology and application. Based on the state-of-the-art of renewable energy power, this paper comprehensively analyzed the costs and benefits of renewable energy power subsidy in China. The analysis results show the cost of renewable energy power subsidy was 0.248 CNY/kWh between 2006 and April 2011, which was distributed among different renewable energy power types (including wind power, biomass power, and solar PV power) or categories (including electricity price, accessing-grid projects, and public independent renewable energy power system). On the other hand, the renewable energy power subsidy also brings benefits to different aspects of the society. Specifically, the environmental benefit amounted to 17.88 billion CNY, and the benefits of guaranteeing energy security, advancing technology innovation and promoting economic development were also noteworthy.

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1. Introduction

In order to advance the development of renewable energy power, Chinese government promulgated the *Renewable Energy Act (REA)* on February 28, 2005, which was put into effect on January 1, 2006 [1]. The *REA* mainly contains six categories, namely resources investigation and development planning, industry guidance and technical support, popularization and application, price management and cost compensation, economic incentives and supervision measures, and legal responsibility. Due to this *REA*, China's renewable energy power has seen a rapid development both in installed capacity and generating capacity in the past few years, even exceeded the planned goals in some aspects [2].

Chinese government has realized that the exploitation and utilization of renewable energy is an important way to solve the problems of environment pollution and energy shortage [3,4]. Therefore, a serial of renewable energy development goals have been set, which claim that the proportion of renewable energy in the total primary energy supply and the share of renewable energy in the total energy consumption will reach to 15% and 30% in 2050, respectively [5,6]. The development situation of China's main power generating types from 1990 to 2012 is listed in Table 1. It can be seen that the wind power as a kind of renewable energy power has developed very fast, the installed capacity of which in 2012 has jumped by 2838.65% compared to that in 2006, and the electricity generation has soared by 1661.4% compared to that in 2007.

Without the financial supports from the government, the renewable energy power in China would not develop so fast. Besides the *REA*, several investment measures aiming to promote renewable energy power development have been taken by Chinese government, as listed in Table 2.

Due to the large capital investments and complicated technical requirements, the renewable energy power in China is still not competitive compared with the conventional power generating types that reflects in the higher generating cost and on-grid price [7,8]. The renewable energy power accessing to the grid will increase the operating cost of power grid company, which originates from the gap between the on-grid price of renewable energy power and the benchmark electricity tariff of desulfurization coal-fired units, the operating and maintaining cost for renewable energy power, and the cost of renewable energy power grid-connected projects. Therefore, the power grid company is reluctant to purchase the renewable energy power generation [9]. To alleviate the barriers of renewable energy power accessing grid, Chinese government has practiced a serial of subsidy policies to provide financial incentives for renewable energy power generators and power grid companies. During the past few years, Chinese government has provided more than 33 billion CNY of financial subsidies, which has promotes the rapid development of renewable energy power, especially wind power (just as shown in Table 1). The renewable energy power subsidy will incur costs, but it can also bring benefits, such as alleviating the environmental pollution. Therefore, it is quite necessary to analyze the costs and benefits of renewable energy power subsidy.

Literature reviews show that majority research articles focus on the concrete contents of subsidy policies for China's renewable energy [8,10–15], and some articles also sketchily discuss the role of subsidy policy on the renewable energy power development [16–19]. However, to the best of our knowledge, few studies have analyzed the costs and benefits of China's renewable energy power subsidy. In order to make an effort to fill this gap, the costs and benefits of renewable energy power subsidy are focused in this

Table 1
Development of China's power generating types from 1990 to 2012.

Year	Installed capacity/GW					Electricity generation/TWh				
	Total	Hydro power	Thermal power	Nuclear power	Wind power	Total	Hydro power	Thermal power	Nuclear power	Wind power
1990	137.89	36.05	101.84	–		621.32	126.35	494.97	–	
1995	217.22	52.18	162.94	2.1		1006.95	186.77	807.34	12.83	
2000	319.32	79.35	237.54	2.1		1386.5	243.1	1107.9	16.7	
2005	517.48	117.39	391.37	6.84		2474.7	401	2018	52.3	
2006	623.7	130.29	483.82	6.85	2.07	2865.7	435.8	2369.6	54.8	
2007	718.22	148.23	556.07	8.85	4.2	3281.6	485.3	2723.3	62.9	5.7
2008	808.73	168.33	621.82	9.11	8.39	3495.8	637	2707.2	69.2	13.1
2009	874.1	196.29	651.08	9.08	17.6	3714.7	615.6	2982.8	70.1	27.6
2010	962.19	213.40	706.63	10.82	31.07	4141.3	662.2	3325.3	73.4	43.0
2011	1055.76	230.51	765.46	12.57	45.05	4721.7	662.6	3897.5	87.4	73.2
2012	1144.91	248.90	819.17	12.57	60.83	4977.4	864.1	3910.8	98.2	100.4

Data Source: National Bureau of Statistics; China Electricity Enterprise Council; National Development and Reform Commission of China.

Table 2
Investment measures for China's renewable energy power.
Source: Documents of related subsidy policies released by Development and Reform Commission of China.

Type	Investment measures	Prospective goals (2020)
Hydropower	From 2006 to 2020, Chinese government plans to invest 1300 billion CNY to develop hydropower and encourages private enterprises to invest small scale hydropower	The installed capacity will reach 0.3 billion kW
Wind power	"New Energy Industrial Revitalization Plan" is proposed, and invests 900 billion CNY	The installed capacity will reach 0.1 billion kW; several 10 million kW-scale wind farm will be built in Gansu, Neimeng, Hebei, Dongbei and Jiangsu provinces
Solar power	"Suggestion on Solar PV Building Application" and "Financial Assistance Fund Interim Measures for Solar PV Building Applications" are proposed, providing 20,000 CNY/kW subsidy for parts of PV building.	The installed capacity will reach 1.8 million kW
Biomass power	Plan to invest 200 billion CNY	The installed capacity will reach 30 million kW, and the proportion of installed capacity in national total will reach 2%

paper. After introducing the development status of renewable energy power in China, the costs and benefits of renewable energy power subsidy will be analyzed in details respectively. Given that many research articles have introduced the subsidy policies of China's renewable energy power [2,6–8,11–13,15–17], the detailed contents related to renewable energy power subsidy policies will not be reviewed in this study.

The paper is organized as follows: Section 2 provides an overview of the development status of China's renewable energy power, including wind power, solar PV power and biomass power. Section 3 analyzes the costs of China's renewable energy power subsidy, and the subsidy costs of wind and biomass power are detailed studied respectively. From the perspective of environmental benefit, energy security, technological innovation and economic development, the benefits of China's renewable energy power subsidy are calculated or analyzed in Section 4. A discussion is given in Section 5. Section 6 concludes this paper.

2. Development status of renewable energy power in China

2.1. Wind power

The decennary from 2001 to 2011 is the rapid development period for China's wind power. The cumulative installed capacity has amounted to 62364 MW in 2011 from 381 MW in 2001, increased more than 163 times. In 2012, the newly added installed capacity of wind power has decreased largely compared to that in the past few years, and the cumulative installed capacity amounted to 75324 MW [20]. The development process of China's wind power in terms of installed capacity in the past ten years can be seen from Fig. 1.

Meanwhile, the offshore wind power development still lies at its early stage. In the *Eleventh Five-Year* period, the *Ministry of Science and Technology of China (MOST)* earmarked funds to support the related institutes to do some researches on key technologies of offshore wind power. In 2007, a specific development plan was proposed in the *Eleventh Five-Year Plan for Renewable Energy Development*, which suggests that the offshore wind power in coastal areas such as Jiangsu province and Shanghai city should be further explored, the technology research and energy resource evaluation of offshore wind energy should be enhanced, and the preparatory works should be planned including the construction of 1–2 offshore wind power pilot projects with installed capacity of 100 MW [21]. The development plan of offshore wind power is listed in Table 3. The above supporting

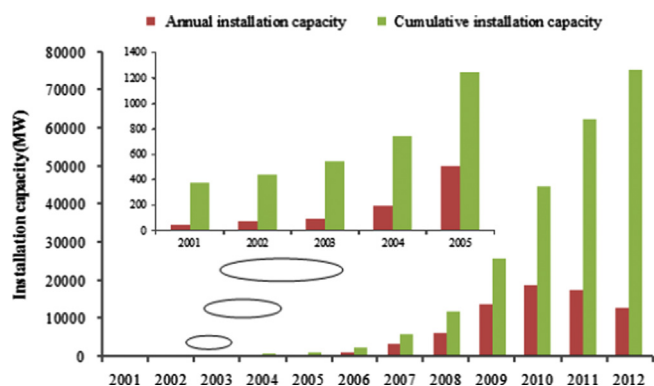


Fig. 1. Wind power development in China.

Table 3

Offshore wind power development plan in China's coastal provinces (unit: MW).
Source: China's wind power development report (2010).

Provinces	Planned installed capacity	
	2015	2020
Shanghai	700	1550
Jiangsu	4600	9450
Zhejiang	1500	3700
Shandong	3000	7000
Fujian	300	1100
Others	5000	10,000
Total	15,100	32,800

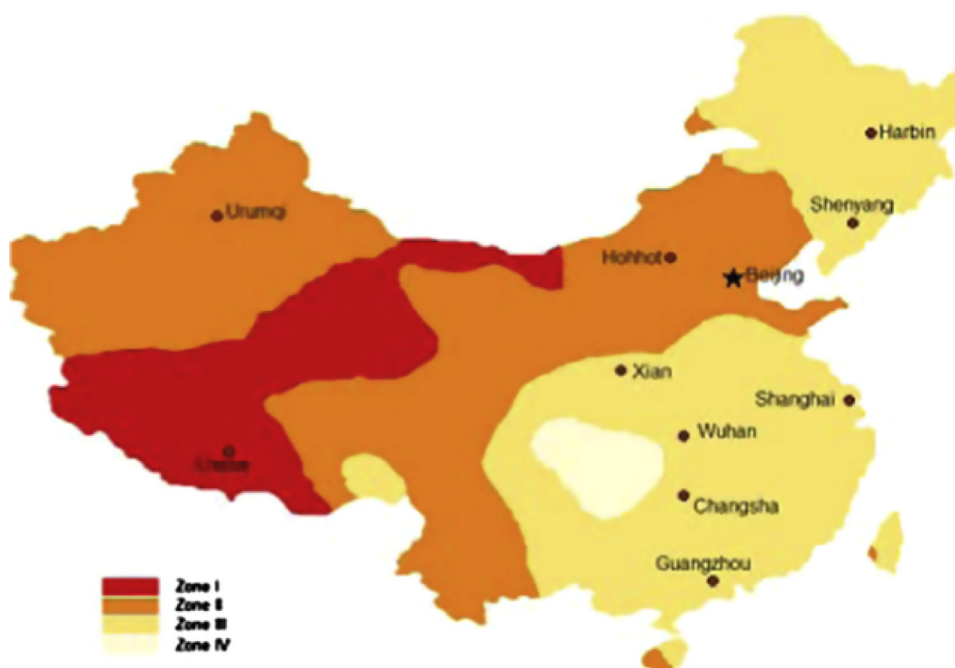


Fig. 2. Solar energy resource distribution in China [26].

measures will contribute to develop the technology and accumulate the experience for future offshore wind power projects, also promote the offshore wind power development.

The reverse distribution of China's wind energy resource and load center indicates that a nationwide clean energy configuration and absorption is needed. Therefore, a large-capacity, long-range energy transmission channel should be built in China [22]. Currently, the large wind power bases exist “spin-off examination and approval” and “into parts” phenomenon. The lag of power grid construction has become the bottleneck of wind power development. Three-North regions (Northeast, North China and Northwest) are the main areas of China's winds power, which are simultaneously the main “abandoning wind power generation” areas. In 2011, the abandoned wind power generation amounted to 12.3 TWh with the abandoned rate of about 16%, and the economic loss reached 6.6 billion CNY. More seriously, the abandoned wind power generation soared to 20 TWh in 2012, and the economic loss exceeded 10 billion CNY [23]. Therefore, some countermeasures are urgently needed.

In 2009, NDRC issued “Notice on the improvement of wind power feed-in tariff policy”, which advised the on-grid power tariff policy for wind power. The benchmark on-grid price of wind power is promulgated based on the wind power resource distribution and wind engineering construction condition, which is divided into four categories: 0.51 CNY/kWh, 0.54 CNY/kWh, 0.58 CNY/kWh and 0.61 CNY/kWh [24]. Compared with the onshore wind power, the off-shore wind power has a higher on-grid price. As a referable off-shore wind power project, Donghai Bridge wind project has 0.978 CNY/kWh of after-tax on-grid price, which is about twice as much as that of onshore wind power. In recent years, the wind turbine price falls sharply, but the costs of land and labor increase. Meanwhile, the drop in wind turbine price mainly results from the scale production and intense price competition instead of the technical progress [25]. Wind power industry in China is changing from quantity to quality, but many development issues need to be solved. Therefore, the on-grid price of China's wind power would not fall in a foreseeable time.

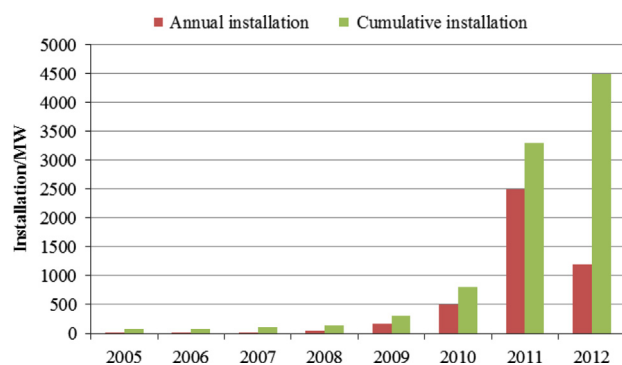


Fig. 3. The installation of China's solar PV power.

2.2. Solar PV power

China's solar resource is abundant, the daily average radiation of which can reach 4 kWh/ (m²/day). However, China's solar resource is greatly diverse in various areas, ranging from less than 2 kWh/ (m²/day) in parts of the southeast (mostly in Zones III and IV), to more than 9 kWh/ (m²/day) in parts of the west (mostly in Zones I and II) [10,16], just as shown in Fig. 2.

The solar photovoltaic (PV) power in China started in 1958 and stepped into the application stage in the 1970s. Since 1993, the output of China's crystalline silicon solar cells has soared by 20–30% annually. During the *Eleventh Five-Year Plan*, the production of solar cell has developed at a growth rate of more than 100% and ranked the first in the world for five consecutive years. Meanwhile, the crystalline silicon cells has accounted for more than 95% of total solar cell production. Thanks to the *Golden Sun Demonstration Program* [27] and *Rooftop Subsidy Program* [28] initiated by the Chinese government in 2009 and 2011 respectively, China's solar PV industry has developed fast.

In 2011, the export value of solar cell reached USD 22.67 billion, which take a 60% share of the world market. Meanwhile, the polysilicon production also saw a steady growth, which amounted to 84,000 M/T ranking the first in the world. In 2012, the annual and cumulative installation of solar PV power increased to 1190 MW and 4490 MW respectively, just as shown in Fig. 3.

Currently, the solar PV power in China is facing severe crisis. Low profit and high debt have become the main challenges for solar PV industry development although the cost has experienced sharp decline since 2009 [29]. Meanwhile, the international trade war related to solar PV industry is warming in recent years. China's solar PV manufacturers are facing the anti-dumping and counter-vailing duties from European countries and USA.

The difficulties that China's solar PV manufacturers are facing are unprecedented, and the business environment is far poorer than expected. The main issues that China's PV power industry is encountering include excess production capacity, disorder competition, low product price, severe damage of capital chain, and obstruction in world competition. Therefore, transforming the industrial development pattern, closing down backward production facilities and developing the domestic market are the urgent tasks on hand. Strong domestic demand market and high-class industrial structure are the survival backbone of China's solar PV manufacturers.

In August, 2013, NDRC issued “Notice on the use of price leverage to promote the healthy development of solar PV industry”, which divides the national regions into three kinds of resource areas and formulates the benchmark on-grid price of solar PV power [30]. The benchmark on-grid price of solar PV power in three resource areas is listed in Table 4. The implementation of benchmark on-grid price policy will promote the development of China's solar PV industry, which may provide a stable domestic solar PV market and then reduce the dependence on overseas market. However, this policy may bring some hidden troubles. The benchmark

Table 4

The benchmark on-grid price of solar PV power.

Resource zone	Benchmark on-grid price	Regions
I	0.90	Ningxia, Haixi, Jiayuguan, Wuwei, Zhangye, Jiuquan, Dunhuang, Jinchang, Hami, Tacheng, Aletai, Kelamayi, regions in Inner Mongolia except Chifeng, Tongliao, Xinganmeng and Hulunbeier
II	0.95	Beijing, Tianjin, Heilongjiang, Jinlin, Liaoning, Sichuan, Yunnan, Chifeng, Tongliao, Xinganmeng and Hulunbeier, Chengde, Zhangjiakou, Tangshan, Qinhuangdao, Datong, Suozhou, Xizhou, Yulin, Yanan, Qinghai, Gansu, the rest of Xinjiang except that in I resource zone
III	1.0	Other regions except that in I and II resource zones

on-grid price policy may cause that many solar PV projects tend to concentrate in the regions with higher benchmark on-grid price. If the power grid constructions in these regions cannot keep pace, the solar PV power generation may be abandoned, just like that of wind power.

2.3. Biomass power

As a kind of renewable energy, biomass energy has the merits of low environmental impact, wide distribution and sustainable utilization. There are rich biomass resources in China, such as biogas, liquid fuels, solid fuels, etc. [31]. The industrialized production of China's biomass power started from 2004. With the supporting policies conducted by the Chinese government such as feed-in tariff and tax incentives, China's biomass power industry has made significant progress in recent years. At the end of 2012, the total installed capacity of biomass power has reached 8500 MW, and the power generation capacity amount to 45.56 billion kWh. The development process of China's biomass power is shown in Fig. 4.

In 2007, China announced *Long-term Renewable Energy Development Plan (2010–2020)*, which set a series of development goals in terms of biomass power. A main goal is that the installed capacity of biomass power will reach 30,000 MW at the end of 2020, accounting for 4% of primary energy consumption. China's biomass power industry is still immature and inexperienced

which faces numerous opportunities and challenges. However, China's biomass power has great development potentials. It is predicted that the exploitation volume of China's biomass energy will increase from 51.97 million tons in 2015 to 119 million tons in 2020 under the current energy demand condition, the details of which are shown in Table 5.

According to Table 5, it can be seen that the total capacity of biomass power will reach 34.5 million kW in 2020 with 28.8 billion m³ of biomass gas, 30 million tons of biomass solid fuel and 12 million tons of biomass liquid fuel. The achievement of this goal requires 51.79 and 119.33 million tce of biomass energy at the end of 2015 and 2020 respectively, which include more than 50% of rural garbage, 20% of manure and 18% of rubbish.

Nowadays, China's biomass power still confronts with the development obstacles, which include the insufficient raw material supply due to the unreasonable distribution of biomass power plants, the weak technical research ability and high power generation cost [12,17]. Therefore, Chinese government needs to clear up the above obstacles to achieve the development goal of 30 GW installed capacity by 2020.

In 2010, NDRC issued “*Notice on the improvement of Agriculture and Forestry biomass power feed-in tariff policy*”, which proposed the 0.75 CNY/kWh of benchmark feed-in tariff policy [32]. Compared to the previous biomass power on-grid price, this benchmark feed-in tariff policy can increase farmers' income and promote the development of agriculture and forestry biomass power industry. To some extent, this policy can mitigate the

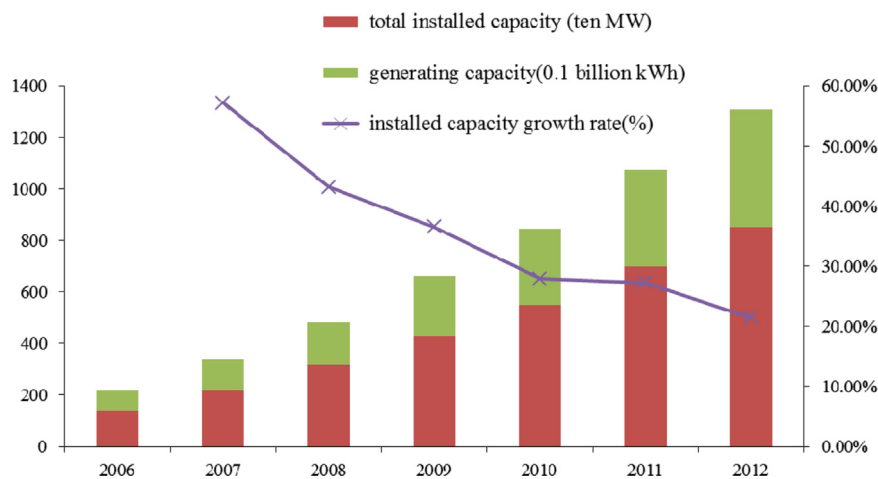


Fig. 4. The development of China's biomass power.

Table 5

The future development of China's biomass energy.

Source: China biomass power technology road map.

Type	2015		2020	
	Capacity	Energy amount (million tce)	Capacity	Energy amount (million tce)
Biomass power (million kW)	14.49	31.92	34.50	74.94
Straw power	6.75	14.45	16.18	34.05
Biogas power	4.07	8.82	10.25	21.93
Garbage power	3.67	8.65	8.07	18.96
Biomass gas (billion m ³)	16.3	11.27	2.88	16.35
Straw gasification	3.7	13.7	1.50	5.49
Biogas	12.6	9.90	1.38	10.87
Biomass solid fuel (million ton)	6.00	3.00	30.00	15.00
Biomass liquid fuel (million ton)	5.00	5.60	12.00	13.04
Ethanol fuel	3.50	3.65	10.00	10.43
Biodiesel	1.50	1.95	2.00	2.61
Total		51.97		119.33

development problems of biomass power industry, such as blind construction and economic loss.

3. The costs of China's renewable energy power subsidy

3.1. Overall analysis of subsidy costs

The renewable energy power in China developed late and required enough financial support. Therefore, a *Development Fund* has been established in China, which is a special fund for research, development, implementation and promotion and other aspects related to renewable energy power. Meanwhile, the government has issued different subsidy policies according to the characteristics of renewable energy power types. Considering renewable energy development status, the price subsidies and quota trading schemes were released by NDRC in 2006, including price subsidy for renewable energy power generation projects, subsidy for renewable energy power accessing-grid projects, subsidy for straw power generation by direct combustion projects and subsidy for public independent renewable energy power system [33].

Renewable energy has been paid enough attentions by Chinese government. As a kind of important energy strategy, the effective subsidy support policies for renewable energy power have been provided in the past few years [2,4–8,11,13,15–19]. The total subsidy quantity for renewable energy power from 2006 to April 2011 is listed in Table 6.

The amount of price subsidy for renewable energy power generation projects in China has kept a steady rise since 2006. In the initiation, the object of subsidy was intended only for wind power. Nowadays, the scope of subsidy has extended to wind power, solar PV power and biomass power. According to the statistical results, wind power got the most subsidies, the project number of which has risen from 31 in 2006 to 590 in April 2011, almost 19 times higher than the original. What cause this happen is that both installed capacity and on-grid generation of wind power have increased very fast in the past few years, so the obtained subsidies for accessing-grid wind projects are much more. The subsidy-obtained biomass power projects amounted to 170, increased by 28 times. Compared with other renewable energy power types, the subsidy for solar PV power developed late but fast, and the projects amounted to 45. This indicates China has realized the importance of developing renewable energy to optimize the energy structure and alleviate the environmental pollution. China is making great efforts to develop various renewable energy power types.

In 2006, the number of subsidy-obtained projects was only 38. However, it reached 806 in April 2011. It can be said that the rapid development of renewable energy power projects benefits from the smooth implementation of subsidy policies. In term of the subsidy per unit electricity generation, the solar PV power take the largest share at the end of April 2011, which has declined to 0.2575 CNY/kWh from 0.350 CNY/kWh in 2006; the second is wind power, which increased to 0.2444 CNY/kWh from 0.237 CNY/kWh in 2006; the last is biomass power, which

increased to 0.2436 CNY/kWh from 0.2412 CNY/kWh in 2006. The main reason is the on-grid generation, power technology and market conditions for various renewable energy power types are different. Compared with the solar PV power, both the wind power and biomass power have more mature technologies and better market environment, so their power generation costs have gradually declined, which put them into the market competition with less subsidy support.

In order to encourage renewable energy power to access grid, Chinese government has implemented several subsidy policies to narrow the gap between power generating cost and sale price. It can be revealed that there has been a steady increase in the on-grid renewable energy power generation, which is an alternative to conventional power generation types such as coal-fired power plants. Affected by the economic crisis, the electricity market collapses in demand, but the subsidy is still enhanced.

Meanwhile, the subsidies for accessing-grid projects are still on the rise, which lay a solid foundation for renewable energy power to be an alternative to fossil energy power. By the end of April 2011, the wind, biomass and solar PV power have gotten certain subsidies for accessing grid. The wind, solar PV and biomass power projects benefit from the subsidy policy, the subsidy-obtained volumes of which account for 36.11%, 28%, and 35.89%, respectively. Compared with the solar PV and biomass power, the subsidy obtained by wind power is still dominant, the main reason of which is the wind power generation is the largest among these three renewable energy power types. Nowadays, due to the strong subsidy support policies, China's renewable energy power market is prosperous.

In order to meet the electricity demand of rural and remote areas, the public independent renewable energy power system also receives subsidies from the government. Wind and solar PV power systems are the main kinds of independent power system in China. Driven by the subsidy policies, the number of independent power system and installed capacity are both on the rise. At the end of April 2011, the number of independent power system projects has increased to 20, and the installed capacity reached 15548.28 MW, almost 8 times of that initially. Meanwhile, the subsidy has amount to 36.28 million CNY.

From 2006 to April 2011, the subsidy volume of wind power was higher than that of solar PV and biomass power, which are 11863.58, 9815.66, and 11769.60 million CNY. While the subsidy per unit power generation of solar PV power was the highest, equaling to 0.258 CNY/kWh. What causes this happen is that the total obtained subsidies of solar PV power have largely increased, but the on-grid power generation is much lower. Meanwhile, in order to make full use of biomass energy and reduce energy loss in rural areas, Chinese government also offered temporary price subsidy for straw-fired biomass power projects. According to the *Energy Development Plan*, subsidy for straw-fired biomass power projects is only provided from 2008 to 2010. Considering the number as well as installed capacity of biomass power projects, this subsidy has produced a remarkable effect. By the end of 2010, the total amount of subsidies for biomass power has reached

Table 6

Subsidy for renewable energy power in China from 2006 to April 2011.

Source: NDRC and author's calculation.

Type	Installed capacity (MW)	On-grid generation (10 ⁴ kWh)	Electricity price subsidy (10 ⁴ CNY)	Subsidy for accessing-grid projects (10 ⁴ CNY)	Subsidy for public independent renewable energy power system (10 ⁴ CNY)	Total subsidy quantity (10 ⁴ CNY)
Wind power	39586.92	4853629.68	1132603	50827.17	2927.93	1186358.472
Biomass power	39445.42	4831473.48	1126443	50517.54	0	1176960.113
Solar PV power	32433.5	3811178.78	938822.5	39417.31	3325.833	981565.656
Total	111465.84	13496281.93	3197868.5	140762.02	6253.7627	3344884.24

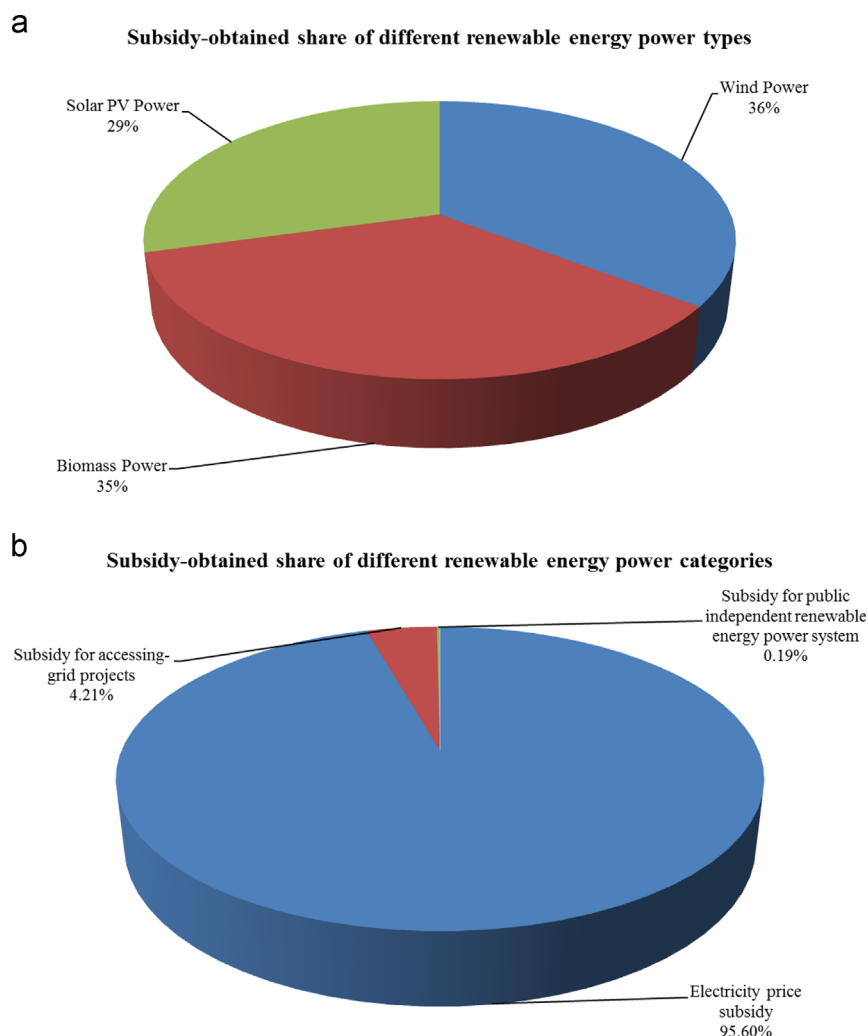


Fig. 5. Distribution of subsidy among different renewable energy power (a) types and (b) categories.

295.35 million CNY. Meanwhile, the installed capacity and number of biomass power projects has increased to 1424 MW and 69 respectively, of which the number is 2 times of that in the early development stage. However, there was a significant fluctuation in subsidy per unit capacity. In the second half of 2009, the subsidy per unit capacity amounted to 208180.3814 CNY/MW, which was lower than that in the first half. From Table 6, it could be concluded that the subsidy policy has effectively promoted the biomass power development.

As listed in Table 6, the total subsidy for renewable energy power amounted to 33448.84 million CNY from 2006 to April 2011, which was distributed among different renewable energy power types or categories, as shown in Fig. 5.

Fig. 5 shows that the electricity price subsidy holds the largest share in the total subsidy, accounting for as much as 95.6%. The subsidy amount for accessing-grid projects and public independent renewable energy power system projects decreased subsequently, which only account for 4.21% and 0.19% respectively. In terms of renewable energy power types, wind power received the majority subsidy, accounting for 36%. The biomass power was following, accounting for 35%. The solar PV power got the least subsidy, accounting for 29%. This is consistent with China's renewable energy power development target. In recent years, wind power has become the focus, and the obtained subsidy is much more than other renewable energy power types. On the other hand, the government also attaches importance to energy

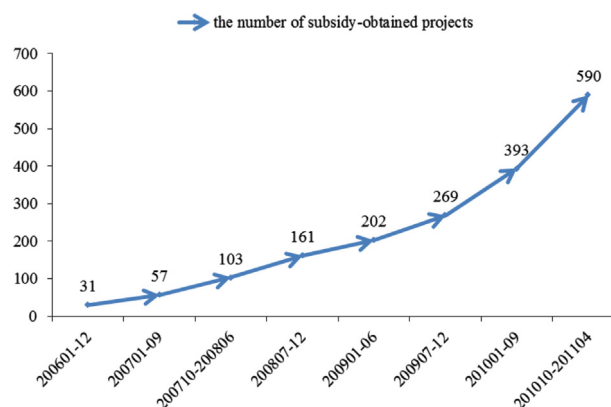


Fig. 6. The number of subsidy-obtained wind power projects.

structure diversification. Therefore, the subsidy share of biomass power has increased from 10% to 35%, and that of solar PV power has also reached 29%.

All in all, driven by the subsidy policy, the installed capacity, on-grid generation and projects of renewable energy power all have a sustained growth, which contribute to the development of renewable energy power. Besides, the specific subsidy policies vary from energy to energy, and the costs are accordingly different. Because the subsidy-obtained proportions and on-grid power

generation of wind power and biomass power are much larger than that of solar PV power, the subsidy costs of wind and biomass power will be discussed.

3.2. Wind power subsidy cost

Due to the abundant resource, bright prospect and wide application, wind power is taken as the major energy in future, and it has received considerable supports from the Chinese government. Since 2002, Chinese government required power grid company to subsidize the cost gap between renewable energy power and coal-fired power [5,8]. Since 2006, the subsidy measures have been further defined, and the subsidy for wind power from the government have been enhanced. The number of subsidy-obtained wind power projects increased from 2006 to April 2011, as shown in Fig. 6. It can be seen that there was a steady rise in the number of the subsidy-obtained wind power projects from 2006 to 2009. However, the number has largely increased since 2010, which increased to 590 at the end of April 2011. The rapid increase of subsidy-obtained wind power projects dues to the blind wind farm construction invested by wind power investors who have inclination to enjoy the subsidy policy for renewable energy power.

Fig. 7 shows the subsidy-obtained on-grid power generation and the corresponding subsidy amount. It can be seen that the subsidy-obtained power generation keeps pace with the subsidy amount, which indicates the wind power development has been boosted by the related subsidy policies. In April 2011, the subsidy amount of wind power increased to 8890.12 million CNY from 226.62 million CNY in 2006, soared by more than 39 times. The subsidy policy has played a quite important role in the wind power development.

The subsidy per unit power generation is shown in Fig. 8, which reveals a nearly downward trend except during the period from January to September of 2010. The subsidy per unit power generation shows a downward trend from 0.2413 CNY/kWh in 2006 to 0.2189 CNY/kWh in 2009. While during the period from January to September of 2010, the subsidy per unit power generation suddenly increased. The reason for this sudden increase is that the drop in on-grid power generation and the implementation of “Modified Renewable Energy Law” on April 2010, which formulates the portfolio standard for renewable energy power generation, guarantees the purchasing of electricity generated by using renewable energy resources in full amount and establishes the renewable energy development fund. From October 2010 to April 2011, the subsidy per unit power generation decreased again, which equals to 0.2158 CNY/kWh. In general, the subsidy per unit power generation declined from

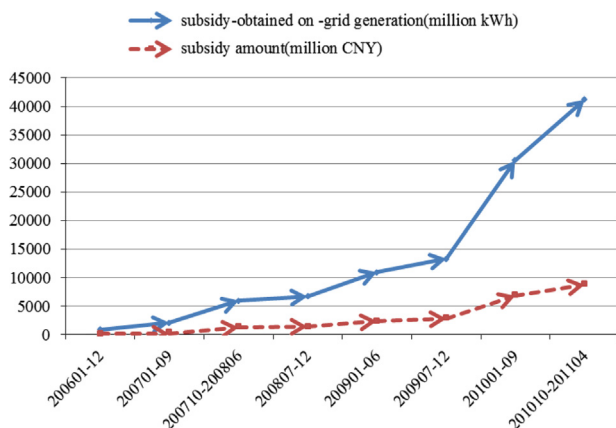


Fig. 7. Subsidy-obtained on-grid power generation of wind power and subsidy amount.

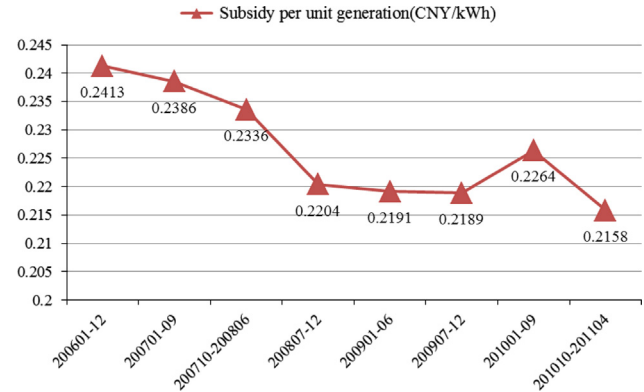


Fig. 8. Subsidy per unit wind power generation.

0.2413 CNY/kWh in 2006 to 0.2158 CNY/kWh at the end of April 2011, decreased by 10.57%. The downward trend of subsidy per unit power generation implies the subsidy for wind power development tends to benign.

From the above analysis, we can know that the subsidy policy has promoted the rapid development of wind power in China. Moreover, the subsidy has also advanced the wind turbine technology and decreased wind power generating cost, which may contribute to enhance the competitiveness of wind power industry. Generally speaking, the subsidy policy has a satisfactory effect on wind power development.

3.3. Biomass power subsidy cost

Due to the abundant resources and technology diversity, biomass power has also a broad application in China [12,14,17,31]. In the past few years, China's biomass power has developed rapidly and the subsidy type also extended.

The number of subsidy-obtained biomass power projects shows a rapid growth trend, which increased to 170 at the end of April 2011 from 6 in 2006 jumped by more than 28 times, just as shown in Fig. 9. The dramatic development of biomass power projects leads to the rapid growth of biomass power in terms of installed capacity and on-grid generation.

The subsidy-obtained on-grid generation of biomass power and the corresponding subsidy amount are shown in Fig. 10. It can be seen that the subsidy-obtained on-grid generation also keeps pace with the subsidy amount, which indicates the biomass power development has been boosted by the subsidy policy. At the end of April 2011, the subsidy amount obtained by biomass power increased to 2284.7722 million CNY from 24.7432 million CNY in 2006 jumped by more than 92 times. The increasing subsidy has also played a very important role in the biomass power development.

The subsidy per unit biomass power generation is shown in Fig. 11, which reveals an irregular trend. The subsidy per unit generation increased at the beginning then dropped later. But since the second half of 2009, it showed an increasing trend again. At the end of April 2011, the subsidy per unit biomass power generation has risen to 0.3182 CNY/kWh from 0.2371 CNY/kWh in 2006 increased by 34.2%. The biomass power in China is just in the initial development stage, and the subsidy-obtained biomass power generation can be easily affected by energy policy environment and industrial situation. Therefore, the subsidy per unit biomass power generation shows the above change characteristics. The increasing subsidy per unit generation is beneficial to the biomass power development. When the biomass power develops more maturely, the subsidy should be reduced, just like that of wind power.

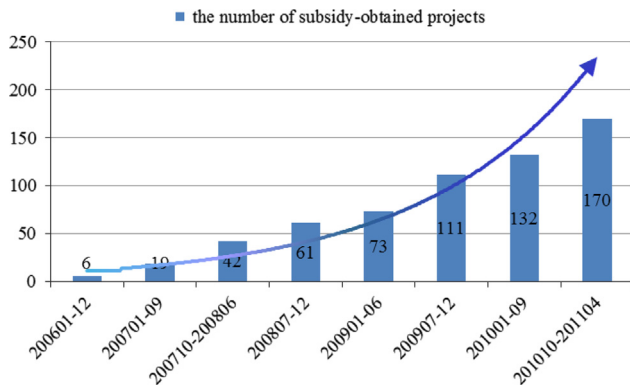


Fig. 9. The number of subsidy-obtained biomass power projects.

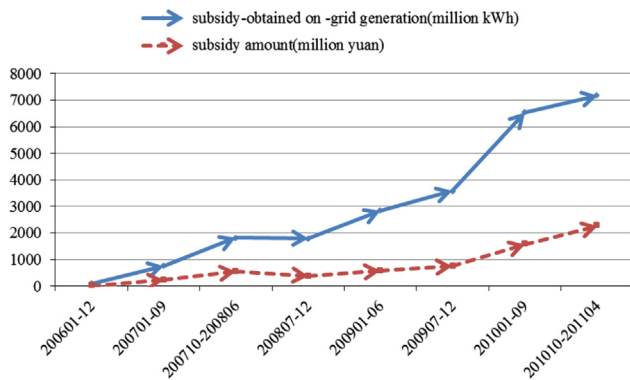


Fig. 10. Subsidy-obtained on-grid generation of biomass power and subsidy amount.

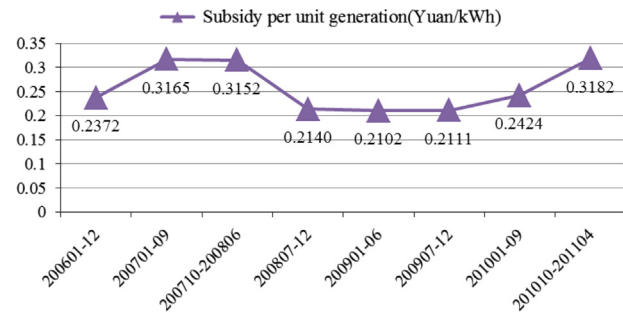


Fig. 11. Subsidy per unit biomass power generation.

In summary, the subsidy amount for biomass power reached 2284.7722 million CNY at the end of April 2011. Driven by the subsidy policy, its installed capacity increased to 2906.92 MW from 84 MW increased by more than 34 times. Meanwhile, the on-grid generation increased to 7179.9834 million kWh from 104.31 million kWh increased by nearly 69 times.

In view of the advantages of renewable energy power, such as carbon emission reduction and energy security protection, Chinese government has offered a large quantity of subsidies to promote the renewable energy power development [2–6]. According to the above analysis, the subsidy quantity for renewable energy power is considerably large. We can safely draw a conclusion that the cost for advancing the renewable energy power development is quite high. And yet there is no denying that the renewable energy power development will bring some benefits, such as environmental improvement, economic growth and energy security guarantee. Thus, it is quite necessary to analyze the benefits

brought by the renewable energy power development boosted by the subsidy policies.

4. The benefits of China's renewable energy power subsidy

In order to develop the renewable energy power, China has invested a large quantity of manpower, material and financial resources. The quantity of subsidy for renewable energy power is quite large. However, the benefits of this subsidy require a further and specific research. According to the characteristics of renewable energy power, a benefit analysis is to be performed from the perspective of environmental benefit, energy security, technological innovation and economic development.

4.1. Environmental benefit

Reducing the greenhouse gas emission is an important issue for global environmental protection and sustainable development. With the clean and low-carbon characteristics, the exploitation and utilization of renewable energy power can largely reduce pollutant emissions and receive significant environmental benefit [34]. In the electricity power generating process, the carbon emission rates of various power generating types can be determined based on the consumed energy resources.

Compared with the conventional power generating types, renewable energy power shows strong positive externality in term of environment, namely the emission reduction of NO_x , SO_2 , CO_2 , CO, TSP, Dust and Residue [35]. The environmental benefit brought by renewable energy power due to the pollutant emission reduction can be calculated by Eq. (1) [35,36].

$$EB = (TQ_R \times \rho_c) \times \sum_{i=1}^n (EV_i \times PE_i) \quad (1)$$

where EB is the environmental benefit, CNY; TQ_R is the total renewable energy power generation, kWh; ρ_c is the share of coal-fired power plant in national total in term of electricity power generation, %; EV_i is the environmental value of the i th pollutant, CNY/kg; PE_i is the emission amount of the i th pollutant discharged by coal-fired power plant, kg/kWh; i represents the pollutant, namely NO_x , SO_2 , CO_2 , CO, TSP, Dust and Residue.

The environmental value of each pollutant discharged by coal-fired power plants in China is listed in Table 7 [35]. According to Tables 6–8 listed in Ref. [36] as well as the technology development status of coal-fired power plants, each pollutant emission quantity of coal-fired power plant can be calculated, just as listed in Table 8.

According to the calculation, the electricity power generation of renewable energy power from 2006 to 2011 amounted to 204.77 billion kWh. Meanwhile, the share of coal-fired power plants in national total in term of electricity power generation was about 75% between 2006 and 2011 [37]. Therefore, the environmental benefit brought by renewable energy power can be calculated according to Eq. (1). From 2006 to 2011, China's renewable energy power offered an electricity supply of about 204.77 billion kWh in total, which indicates a decreased emission of CO_2 , SO_2 , NO_x , CO, TSP, Dust and Residue by 98250053, 270916, 271776, 14836, 7310, 8062976 and 3074682 t respectively. The environmental benefits of these pollutants emission reduction are

Table 7
Environmental value of each pollutant (Unit: CNY/kg).

Pollutant	CO_2	SO_2	NO_x	CO	TSP	Dust	Residue
Value	0.13	6.00	8.00	1.00	2.20	0.12	0.10

12772.51, 1625.50, 2174.21, 14.84, 16.08, 967.56 and 307.47 million CNY respectively. Therefore, the total environmental benefit brought by renewable energy power due to the pollutant emission reduction amounts to 17.88 billion CNY, just as shown in Fig. 12.

4.2. Energy security

With the rapid change of global pattern and international order, China's energy security is facing many new challenges [38]. The rapid rise of economic power as well as energy consumption in China has attracted wide international attentions. Nowadays, China's dependence degree on foreign energy is quite high. China's energy consumption is the largest in the world, accounting for about 20% of the world total, yet the GDP only accounts for less than 10% [39]. In the past ten years, the accumulative energy consumption increment accounts for 53% of the world total, and the annual average growth rate is three times as much as the world [38]. Although China has developed as one of the largest energy producers, the energy resource endowment is not high. In 2011, China's dependence degree on foreign energy exceeded 13%, and the dependence degree on foreign oil increased to 57%. Not only oil, gas and uranium but also coal has the demand of import [40].

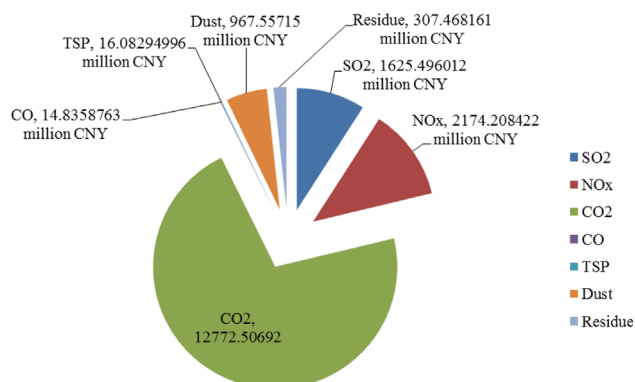
By estimated, the remaining exploitation duration of coal, oil and nature gas resources in China is less than 100, 15 and 30 years respectively, the reserves of which are all below the world average level [29]. However, China's economy requires plenty of energy to keep pace with the rapid development, which is one of the contributory factors for the rising dependence on foreign energy. It is predicted that China's oil import will rise, and the dependence degree on foreign oil will be over 60%. So, the energy security risk will also increase in the next 20 years [41]. To some extent, the serious pressures from the energy utilization and power supply in China can be eased in way of developing renewable energy power.

Actually, China's energy structure has been optimized by the renewable energy power development in the past few years, but the energy supply tension is still not relieved significantly, as shown in Fig. 13.

It can be seen that the import quantity of both coal and oil rise constantly, but the growth ratio dropped. In 1993, China became a net oil import country, and the oil import quantity keeps high even in the period of renewable energy power rapid development.

Table 8
Each pollutant emission quantity of coal-fired power plant (Unit: kg/MWh).

Pollutant	CO ₂	SO ₂	NO _x	CO	TSP	Dust	Residue
Q	639.73	1.764	1.7696	0.0966	0.0476	52.5	20.02



Total environmental benefit, 17.88 billion CNY

Fig. 12. Environmental benefit of pollutant emission reduction.

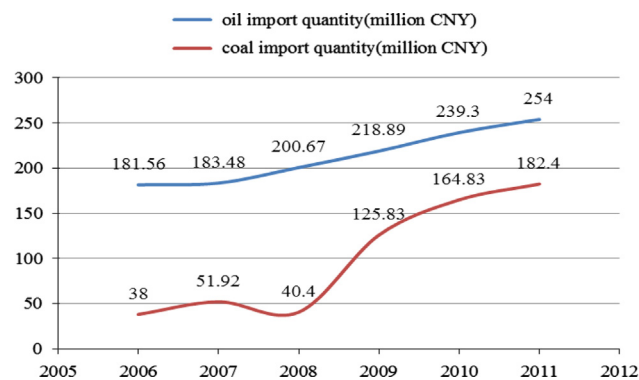


Fig. 13. The import trend of coal and oil in China.

At the end of 2011, the oil import quantity reached 254 million tons, and the dependence degree on foreign oil reached 56.5%. In theory, the rapid economic growth in China will push up the oil import quantity, which will lead to the increasing growth ratio of oil import. However, in the recent years, the growth ratio of oil import is nearly constant. One of the main reasons is the rapid renewable energy power development has advanced the China's energy structure and certain conventional power generation has been substituted by renewable energy power generation.

Because of abundant reserve, the coal import quantity is lower than oil, but it also keeps a rapidly increasing trend. In 2008, the coal import quantity was lower than that in 2007 by 20.82% due to the decline of domestic coal demand influenced by the economic crisis. With the market recovery, the import quantity increased significantly in 2009, which is more than three times that in 2008. After 2009, the growth ratio of coal import declines again.

From the above analysis, we can conclude that the renewable energy power development stimulated by subsidy policy has played an effective role in guaranteeing the China's energy security.

4.3. Technological innovation

Generally speaking, the renewable energy power development may give rise to a considerable technological innovation, which the cost gap between renewable energy power and conventional power can be narrowed and the renewable energy can receive wide application [42].

In China, compared with other renewable energy power types, wind power has comparatively mature technology, the power generating cost of which almost equals to that of conventional power types nowadays [8–9,11,14]. However, the costs of solar PV and biomass power are much higher than conventional power types, which are technologically immature with a not enough bright prospect [7,10,16]. Compared with the wind power, both solar PV and biomass power still need great improvement in term of technology and cost. In addition, there are some uncertain factors affecting their development. Over all, the renewable energy, especially biomass power and solar PV power, have a certain development potential in both technology and cost.

In the last few years, China has focused on the development of the above three renewable energy power types and made some achievements. In term of wind power, China has held the manufacture technology of large capacity single machine and MW-level variable pitch control with the independent intellectual property right. From 1992 to 1996, the unit capacity of wind power was 200–300 kW, and it increased to 600 kW from 1997 to 2002. After 2002, the unit capacity is on steady increase. For instance, the first 5 MW wind machine was produced by HuaRui Corporation in 2010. Meanwhile, the research on 6 MW wind machine which possesses the world advanced technology is in progress. For the

feed-in grid technology, the related standard was set to deal with the problems such as voltage sag, harmonic and flicker. For offshore wind power technology, the research focuses on offshore wind farm siting, turbine installation, corrosion-resistance of parts, testing technology, etc. However, there are still some defects in China's wind power technology, such as the lack of independent intellectual property core technology, the poor reliability of some domestic equipment and quality problems. For example, the frequent occurrences of wind power accidents in JiuQuan city on February 24 and April 25, 2011 and GuaZhou city on April 17, 2011 caused thousands of wind machine out-of-services, which affect the normal operation of power grid. By analysis, the accidents primarily result from the technological disadvantages in wind machine.

Supported by the national industry plan and national key basic research development plan including "973 Plan" and "863 Plan" program, the gaps between China and other advanced countries in term of battery package, power in-grid technology and systems integration have been narrowed. The development and research on key technologies such as polycrystalline Si thin-film battery and amorphous silicon thin-film battery have been launched. Supported by Chinese government, a lot of solar PV-related enterprises operate well. For instance, *Suntech* is among the world's top five, and its 16% of formation efficiency has reached the world advanced level. *TuoRi* and some other enterprises are also able to produce amorphous silicon thin-film battery on a large scale with an annual production capacity of 10 MW. In terms of technology application, many attentions are paid to roof power generation and high-voltage grid technology. In future, a series of roof power generation system with a capacity of 10–50 kW and low/high-voltage solar PV plants with a capacity of 100 kW will be built.

4.4. Economic development

It is well known that the renewable energy power cost is higher than that of conventional power types, which will lead to a higher on-grid price. To solve the higher on-grid price issue, Chinese government rules that the electricity consumers need to share the additional cost related to the renewable energy power assessing to the power grid. Although this measure can promote the renewable energy power development, it also increases the financial burdens on electricity consumers, which can be seen in the changing trend of China's electricity sale price from 2006–2010 shown in Fig. 14.

The successful experiences of renewable energy power application show that national economy can be promoted by renewable energy power development. Currently, renewable energy power has formed an emerging economic growth sector. One hand, China's wind power industry kept an annual growth rate of 30% in the past five years (2006–2010), and almost 30 enterprises including large state-owned energy companies, private enterprises and foreign companies were planning to invest in wind power industry. In 2006, there was an investment of 10 billion CNY in the wind power industry with the installed capacity rising by 76%. In 2007, the amount of investment rose to 24 billion CNY, which drives the development of related manufacturing industry. In order to achieve the goal of 30 million kW wind power installed capacity by 2020, there will need a total investment of 290 billion CNY. This will drive the output value of related industry to reach 320 billion CNY and create 2 million jobs. On the other hand, China's solar PV power stations have been widely installed in rural and pastoral areas in the past few years. Over 40 small-scale solar PV plants have been built with 600 kW of installed capacity. Almost 30 enterprises from 10 provinces have entry the solar energy industry with an investment of 20 billion CNY. All in all, the development of renewable energy power has promoted the economic development.

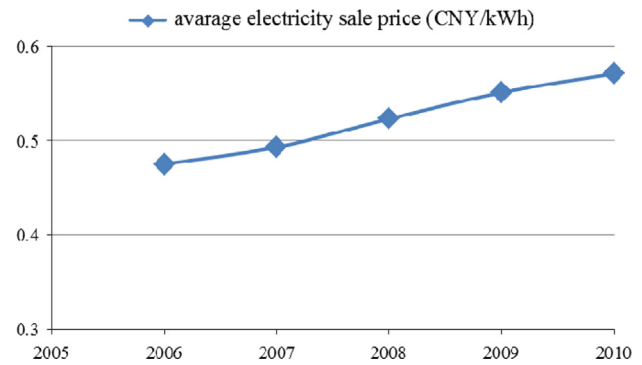


Fig. 14. Average electricity sale price in China.

5. Discussion

There is no doubt that China's renewable energy power such as wind power and solar PV power would not develop so fast without the subsidy policies. Since the implementation of "Renewable Energy Law", China's renewable energy power industry has witnessed rapid development. China sets off an upsurge on constructing renewable energy power projects, which benefits from the related subsidy policies. However, due to less consideration on the power grid transmission capacity, there exists inconsistent between electricity generation side and power grid side, which leads part of renewable energy power generation cannot be delivered out and cannot also be consumed by local electricity consumers. This result in the incident that abundant renewable energy power generation has to be abandoned. Therefore, some renewable energy power generation that obtains the subsidy cannot be consumed, which wastes the nation's capital resources and violates the original intention of subsidy policies.

Predictably, China's renewable energy power will keep fast development in the coming years. If the renewable energy power still obtains the financial subsidies according to the current subsidy policies, the government will face increasing pressures in term of subsidy funds. From an economic perspective, the subsidy policy will play a large role in renewable energy power development in the short term. However, in the long term, the subsidy policies cannot enhance the power enterprise's competitiveness or promote the sustainable and healthy development of renewable energy power industry to some extent. Therefore, the subsidies for renewable energy power should be decreased or even eliminated based on development status as well as planned goals of renewable energy power industry in the near future, which will advance the technological progress and healthy development of renewable energy power industry and also alleviate the nation's financial burden.

6. Conclusions

This paper analyzed the costs and benefits of renewable energy power subsidy provided by Chinese government from 2006 to April 2011. Based on the above analysis, it can be concluded that:

- (1) The subsidy for renewable energy power from 2006 to April 2011 amounted to 33448.84 million CNY, and the subsidy cost per kWh equaled to 0.248 CNY.
- (2) In terms of subsidy category, the most subsidies were used for electricity price category, accounting for as much as 95.6%. In terms of power types, wind power received the majority subsidy, accounting for 36%.

- (3) The rapid renewable energy power development boosted by subsidy policies produced 17.88 billion CNY of environmental benefit, optimized the China's energy structure which played an effective role in guaranteeing the China's energy security, advanced the technological innovation which the cost gap between renewable energy power and conventional power was narrowed, and promoted the national economic development with a bright industry development prospect.

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